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THE LIFE HISTORY OF *GONGYLONEMA SCUTATUM*

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In April, 1911, the writers undertook some investigations in regard to insects as intermediate hosts of parasites. The investigations of the senior author were carried on at the Experiment Station of the Bureau of Animal Industry at Bethesda, Md., and in the laboratories of the Bureau at Washington, and later at Colorado Springs, Colo. Those of the junior author were carried on at Colorado Springs, Colo. Particular attention was paid to the dung beetles, as it seemed evident that these insects in working through fresh feces as is their habit, would have the first opportunity to ingest eggs of worms parasitic in the digestive tract of cattle, sheep, and other live stock. Such beetles as species of *Aphodius*, furthermore, appeared small enough to be readily ingested by grazing animals, and the beetles' habit of flight from one manure deposit to another offered chances for such ingestion, as the beetles' flight commonly terminates on grass and herbage with which they might readily be swallowed by cattle or sheep.

The dissections by the senior author of *Aphodius femoralis*, *A. granarius*, *A. fimetarius* and *Onthophagus hecate* resulted in the finding of encysted larval nematodes in the body cavity. These cysts were about 0.5 mm. in diameter and as many as 8 were found in one *Aphodius* and 15 in one *Onthophagus hecate*. One larva which was measured was 2 mm. in length and 50 μ in thickness. Viewed from in front the head shows a narrow mouth aperture elongated dorso-ventrally and surrounded by a chitinous border, which is oblong quadrangular in outline with rounded corners, and measures about 12 μ dorso-ventrally and about 8 μ from side to side. A short distance posterior of the edge of the chitinous border are 2 sub-dorsal and 2 sub-ventral papillae. The chitinous border of the mouth is raised above the surrounding surface of the head and resembles a projecting flange when the head is viewed from the side. The slender pharynx is 40 μ long. The esophagus measures about 1.5 mm. in length, and is differentiated into a slender anterior portion about 225 μ long, and a more granular posterior portion of somewhat larger diameter. The anus is about 100 μ from the tip of the tail. The latter is blunt and is supplied with two or three very small short conical processes. The excretory

pore is about 200μ from the anterior end of the body. About 140μ from the anterior end of the body the esophagus is surrounded by a nerve ring.

In June a number of larvae of *Aphodius* spp. were examined, and in these were discovered some young nematodes which agreed perfectly with the unhatched embryos of *Gongylonema scutatum*. The embryo of *Gongylonema scutatum* is very distinctly annulated in the head region on the side opposite the mouth. The mouth is not terminal, but is a triangular aperture on one side of the head, with a curved hook-like process projecting from it. The tip of the tail is bluntly pointed.

The finding of these newly hatched larvae in the same host beetles as the encysted larvae was fairly good evidence that they were of the same species and, in view of the failure to find them in adult beetles, seemed to indicate that the eggs of the worm were principally ingested by the beetle while it was in the larval stage.

In July both of the writers were in Colorado and the examination of *Aphodius coloradensis*, *A. vittatus*, and *A. granarius* showed the presence of an encysted larval nematode exactly similar to that found at Bethesda. These beetles were collected from sheep manure at points 17 miles east and 75 miles northeast of Colorado Springs.

The observations in regard to the finding of *Gongylonema* larvae in larval and adult dung beetles were briefly alluded to in the Twenty-eighth Annual Report of the Bureau of Animal Industry for the year 1911, as follows:

"Important facts have been determined bearing upon the life history of the gullet worm of sheep and cattle."

In 1912 the encysted larval forms of *Gongylonema* were again observed in the dissection of insects in connection with other investigations in Colorado, but no further work was carried on that year.

In 1911 an experimental feeding was made by the senior author. Four or five larval *Gongylonema* were fed to a white mouse on May 13 and 14 more were fed to this mouse on May 17. On June 14, 32 and 28 days, respectively, after these feedings, the mouse was killed and examined. No worms were found. This result tended to show that the parasite is not transmissible to mice and that the larvae were not those of *Spiroptera obtusa* whose larvae, occurring in the meal worm, show very striking similarities to those which the present writers assumed belonged to *Gongylonema*.

In 1913 an experimental feeding was made by the junior author at Colorado Springs. During the two months from May 10 to July 9 inclusive, a sheep was fed a total of over 250 specimens of *Alphodius coloradensis*, *A. congregatus*, *A. fimetarius*, *A. granarius*, *A. inquinatus*, and *A. vittatus*. A dissection of a large proportion of these beetles showed a very small number of them to contain encysted *Gongylonema* larvae.

Three of the larvae obtained on dissection were also fed to this sheep. This sheep was killed November 18 and was found to have 7 *Gongylonema scutatum* in the esophagus, together with the characteristic lesions showing where a few others had been at one time. A companion sheep kept under identical conditions for a year and a half, but not fed any specimens of *Aphodius* did not develop any infection with *Gongylonema*. Thirty-five lambs raised under experiment conditions very much the same as those of the two sheep mentioned above were killed during the course of the three years 1911 to 1913 inclusive, and these were all free from *Gongylonema*. This furnishes an abundance of checks in support of the experimental finding that species of *Aphodius* act as intermediate hosts of *Gongylonema scutatum*.

During the summer of 1914 some additional work was done investigation of this life history. Cattle weasands heavily infested with *Gongylonema scutatum* were sent in from Indianapolis, Ind., by Dr. G. W. Butler, the egg-bearing worms cut into small fragments, mixed with small quantities of bread or other food and fed to specimens of *Aphodius* and to croton bugs, *Ectobia germanica*. The day after the insects were exposed to infection in this way, empty shells of *Gongylonema* eggs were found in the intestine, and the following day numbers of free embryos were found. Other eggs were found unhatched in the intestine and in the feces of the insects, but these were obviously eggs which had not yet developed to the infective stage. These findings demonstrated that the eggs would hatch when ingested by the adult as well as by the larval *Aphodius*.

The young larvae found two days after exposure to infection were about 250 μ long and were apparently increasing in size. In the course of a week the larvae found were very much thicker. At the end of two weeks the larvae were about three times as thick as the original embryos and were apparently on the verge of an ecdysis. At this time they show a complete alimentary tract. The esophagus is about three-eighths to four-ninths of the entire body length, and is surrounded by a nerve ring a short distance in front of its middle. The rectum is a well-marked structure of rather large diameter, and posteriorly is closed by a plug of tissue which projects from the ventral surface of the body. This plug marks the location of the anus and is one-sixth of the body length from the posterior end. About this time there is an ecdysis and the cephalic annulation is lost.

At the end of three weeks the head is more pointed but the flange-like margin of the lips is not yet developed. The rectum is no longer prominent, but the button marking the position of the anus persists. The larvae are now much longer.

At the end of about a month the larvae are encysted in the final stage. The head has the structure described in the first part of the paper and the anal button is lost. In favorable specimens cervical papillae may be seen about half way between the nerve ring and the anterior end of the body.

An experimental feeding to croton bugs of eggs of *Gongylonema* from the gullet of a hog, gave substantially the same results. The larvae were encysted in the final stage at the end of a month.

A rabbit was fed with three *Gongylonema* larvae on one occasion and with two on another. Two months after the first feeding and one month after the second, the rabbit was killed and the mouth, pharynx, and stomach were examined. No worms were found. A guinea-pig was fed with three *Gongylonema* larvae on one occasion and three more on another. Five weeks after the first feeding and three weeks and two days after the second feeding it died. No worms were found.

August 18 a sheep was fed eleven *Gongylonema* larvae from a croton bug and a hog was fed a croton bug containing possibly fifty larval *Gongylonema*, the larvae having been developed by feeding eggs of *Gongylonema* collected from cattle. On August 25 the same sheep and hog were fed more croton bug material heavily infested with similar larvae. The hog was killed October 17, but showed no infection. The failure to infect the hog with the nematode from sheep and cattle is suggestive of a specific infectivity and strengthens the idea that the hog nematode is a distinct species. The sheep was killed November 23 and the gullet found heavily infested with *Gongylonema*, the females of which were mature and full of eggs.

While the work noted above was in progress, a very interesting paper appeared, dealing with the life history of another species of *Gongylonema*. Fibiger (1913) published a note in which he stated that he had found in rats a gastric carcinoma etiologically related to a species of *Spiroptera*. A year later, Fibiger and Ditlevsen (1914) published their complete study of the worm itself and the lesions attributed to it. The worm in question, called by them *Spiroptera* (*Gongylonema*) *neoplastica*, should be called *Gongylonema neoplasticum*. *Gongylonema* is a well established genus and there is no reason to question the propriety of including this species in *Gongylonema*, notwithstanding its lack of one characteristic of this genus, namely, the presence of cervical papillae. It is even not impossible that cervical papillae may be present, as these structures are frequently very difficult to distinguish in some species of nematodes and may be overlooked in numerous specimens, finally being discovered when a specimen happens to be turned into just the right position.

Fibiger and Ditlevsen have made an excellent study of the life history of this worm. It was found in the first instance in rats, but it appears to be communicable to rodents generally as it was transmitted to the following: *Mus decumanus*, *Mus rattus*, *Mus musculus*, *Lepus cuniculus*, *Cavia cobaya*. The parasite occurred in the squamous-celled epithelium of the anterior portion of the digestive tract, including the mouth, tongue, esophagus and fundus of the stomach. In these regions the worm gave rise to a proliferation of the epithelial elements, originating as a circumscribed or diffuse hypertrophy associated with a slight inflammation, going on to the formation of papilloma, and terminating in distinct carcinoma with occasional metastases.

The eggs produced by the female worm are passed in the feces of the infested rodent and were first found to be ingested by *Periplaneta americana*, but were also found infective for *Periplaneta orientalis*, *Ectobia germanica* and *Tenebrio molitor*. Twenty days after the ingestion of the eggs by the insects, the fully developed larvae are found coiled in the muscles of the prothorax and limbs. It will be noted that this site is different from that of *Gongylonema scutatum* larvae. The location of the embryonic and larval forms after the first day following the ingestion of the eggs and up to the time they are found in the musculature of the prothorax and limbs was not determined.

It is evident from the above that the life history of the two species, *Gongylonema scutatum* and *Gongylonema neoplasticum* is much the same in that the larval stage is spent in insects, at least one of which, *Ectobia germanica*, is common to both, and that the adult worm is found in the epithelium of the gullet in the primary host in both cases. The worms differ in that the larval stage of the rodent nematode is found in the musculature of the insect host, while the larval stage of the ruminant nematode is found encysted in the body cavity. They also differ in that the rodent nematode commonly occurs in the tongue, mouth and cardiac portion of the stomach as well as in the esophagus. Finally, the rodent nematode has the unusual power of producing neoplastic changes in its primary host, while there is yet no evidence that the ruminant nematode is more than a rather innocuous parasite.

The life history of *Gongylonema scutatum* and *G. neoplasticum* is strikingly similar to that of *Spiroptera obtusa*, which occurs in its adult stage in the intestine of rats, mice and similar rodents.

Leuckart (1867: 113-115) and Marchi (1871) found that the larval development of this parasite occurs in the meal worm (larva of *Tenebrio molitor*). The eggs, which resemble those of *Gongylonema* and contain similar embryos, when swallowed by meal worms hatch out and release the embryos. These embryos pass through the wall of the

alimentary tract, and develop in the midst of the fat surrounding it, becoming enclosed in connective tissue cysts. The larval development is complete in about six weeks after ingestion of the eggs. The fully developed larva measures from two-thirds of a millimeter to nearly a millimeter in length. The head, as described, is supplied with two triangular papillae curved on their inner surfaces, and surrounding the mouth except laterally. The tip of the tail is supplied with several small conical papillae. The excretory pore is about 100μ and the base of the esophagus about 300μ from the anterior end of the body.

Judging from Marchi's description and figures one of the most striking differences between the full-grown larvae of *Spiroptera obtusa* and *Gongylonema* is that the esophagus of the former is only about one-third the length of the body, whereas the esophagus of the latter is fully two-thirds the body length.

As a postscript it may be noted that since this paper was read at a meeting of the Helminthological Society of Washington, Dec. 17, 1914, an additional intermediate host of *G. scutatum* has been found, namely, *Onthophagus pennsylvanicus*. Beetles of this species collected from sheep pastures near Vienna, Va., during the summer of 1915 were found to be commonly infested with the encysted larvae.

SUMMARY

The eggs of *Gongylonema scutatum* present in the feces of sheep and cattle infested with the adult parasite, hatch out when swallowed by insects of various species.

The larvae thus released from the eggs, pass into the body cavity and reach the final larval stage in about a month. In this stage the larva is coiled into a spiral and is enclosed in a capsule about half a millimeter in diameter. The length of the fully developed larva is about 2 mm. and the esophagus equals about two-thirds the body length. The mouth, elongated dorso-ventrally, is surrounded by a flange-like chitinous border.

Sheep fed upon insects containing these larvae became infested with *Gongylonema*. A hog fed upon croton bugs artificially infested by feeding with eggs of *Gongylonema* from cattle failed to become infested. A mouse, rabbit and guinea-pig fed with *Gongylonema* larvae from beetles found in sheep manure, or from croton bugs artificially infested by feeding *Gongylonema* eggs from cattle, also failed to become infested. Failure to produce infestation in these various animals indicates that the *Gongylonema* of sheep and cattle (*G. scutatum*) is not transmissible to hogs, mice, rabbits or guinea-pigs.

Gongylonema larvae have been found in various species of dung beetles collected from sheep manure, namely, *Aphodius femoralis*, *A. granarius*, *A. fimentarius*, *A. coloradensis*, *A. vittatus*, *Onthophagus*

hecate, and *O. pennsylvanicus*. They have been developed in various species of *Aphodius* and in croton bugs (*Ectobia germanica*) by feeding the eggs of *Gongylonema scutatum* from cattle. The feeding of eggs of *Gongylonema* from the gullet of a hog (presumably *G. pulchrum*) to croton bugs also resulted in the development to encysted larvae.

Under natural conditions the usual intermediate hosts of *Gongylonema scutatum* are probably dung beetles of various species.

The life history of *G. scutatum* is similar to that of *G. neoplasticum* of rats, mice and other rodents, the intermediate stage of the latter having been found by Fibiger and Ditlevsen to develop in roaches (*Periplaneta americana*, *P. orientalis*, and *Ectobia germanica*) and in a beetle (*Tenebrio molitor*). It is also similar to that of another rat and mouse parasite, *Spiroptera obtusa*, whose intermediate host was found by Leuckart and Marchi to be the larva of a beetle (*Tenebrio molitor*).

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